

AC DEMAGNETIZATION OF SATELLITE COMPONENTS

John D. Watson

INTRODUCTION

The magnetic field associated with satellite components, which arises from the magnetic materials used in construction, can be detrimental to satellite performance. This is particularly true if the satellite's primary mission is measurement of earth's magnetic field at several radii from the earth's surface; it may turn out that the magnetic field of the satellite, because of remanent magnetization of ferromagnetic materials used in its construction, is of the order of the field to be measured.

Most of the remanent magnetization in a satellite component may be removed by a demagnetization process. Demagnetization consists of a cycling of the hysteresis loops and, consequently, the remanent magnetization from some maximum value (depending upon the amplitude of the initial demagnetization field strength) to zero.

The maximum amplitude of the initial field strength must be of the order of the coercivity of the material to ensure removal of saturated remanences.

The dc demagnetization system used at Goddard's magnetic test facility makes use of Helmholtz coils energized by alternate polarity pulses to produce the diminishing magnetic field essential to the cycling process. This system operates to measure the field of the component to be demagnetized, determine the direction of the maximum field intensity, align this direction with the axis of the Helmholtz coils, then demagnetize the component along this axis. Satisfactory results have been obtained with this method.

An objective of the Summer Workshop was to determine if an ac demagnetization process would be more effective than the process just described for reducing permanent magnetization to a minimum intensity.

Normal procedure in ac demagnetization^(1, 2) is to randomly rotate or tumble a component having an undesirable remanent magnetization in an alternating magnetic field which may be reduced smoothly to zero from a chosen maximum value. It is important that the rate at which the ac field is decreased be even and slow, compared with the rotation speed of the component. The motion of the component in the field should be as random as possible to ensure that all directions in the component are subjected to the demagnetization action of the alternating magnetic field.

An ac demagnetization system was built to satisfy the requirements stated.

GPO PRICE \$ _____

OTS PRICE(S) \$ _____

Hard copy (HC) 1.00

Microfiche (MF) .50

C-5

N 65 151 38
Code 1
TMX-54944
J.P. 7
Cat-32

THE AC DEMAGNETIZATION APPARATUS:

THE TUMBLING SYSTEM

A tumbling system (Figure C-1) was designed to provide random motion of the component. A diagram of the system is given as Figure C-2. The system provides rotation of a component about three mutually perpendicular axes with a single drive to the outer rectangular frame. The component to be demagnetized is placed inside the inner rectangular frame. The drive-shaft turns the outer rectangular frame A. Pulley D is fixed to support F; as frame A rotates, belt G is wound around fixed pulley D. As this belt is also linked to pulley E, the latter rotates and turns the inner frame B, which rotates about an axis perpendicular to that of frame A. The same procedure is used to obtain rotation of the inmost frame; pulley H, fixed to frame A, serves to move belt J around as frame B rotates, turning pulley I to rotate frame C about an axis perpendicular to that of frame B.

It is evident from this description that there are always two mutually perpendicular axes of rotation; the axis of the inmost frame is continually travelling from a position parallel to that of the first axis to a position mutually perpendicular to both the other axes. The axes have speeds of rotation in the order of 18: 19: 20, the inmost frame turning at the fastest speed and the outer frame at the slowest speed. With this ratio,

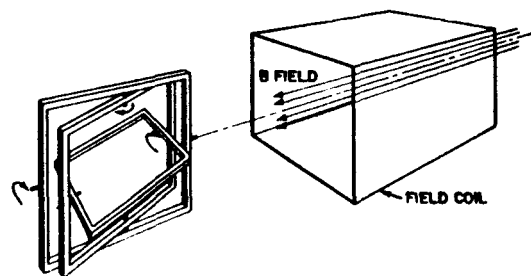


Figure C-1—Artist's concept of tumbler and coil.

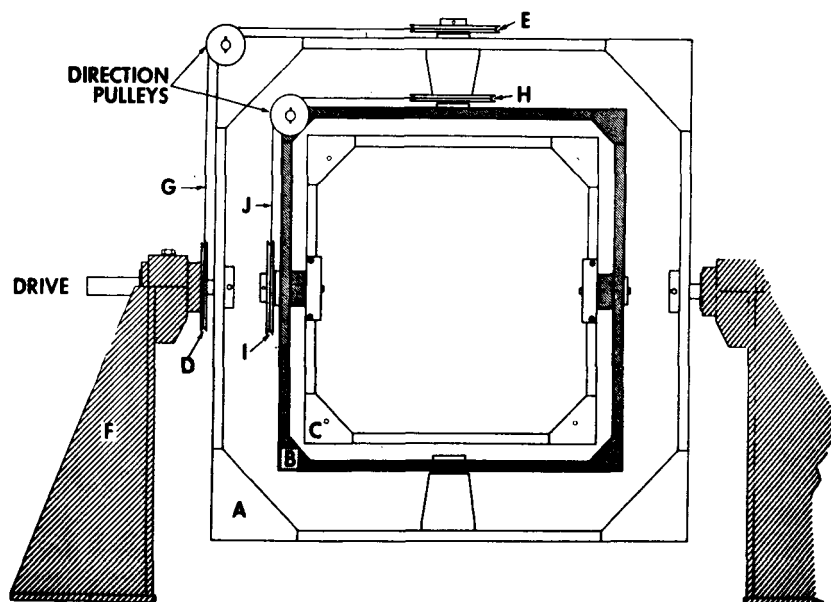


Figure C-2—AC demagnetization apparatus, structural diagram.

any direction in the component performs a Lissajou figure during rotation, and all directions of the component are subjected to the demagnetizing action of the field.

The inmost rectangular frame measures 24 inches to a side, providing 8 cubic feet of working volume. The belts are rubber O-rings which work reasonably well for the designed rotation speeds of the tumbler. All materials used in construction are nonmagnetic.

THE COIL

The coil which provides the magnetic field was designed and built at Goddard. It consists of a single layer of 280 turns of No. 8 double-cotton-covered square copper wire wound on a wooden frame in the shape of a cube. Figures C-3 and C-4 are photographs of the tumbler and the coil.

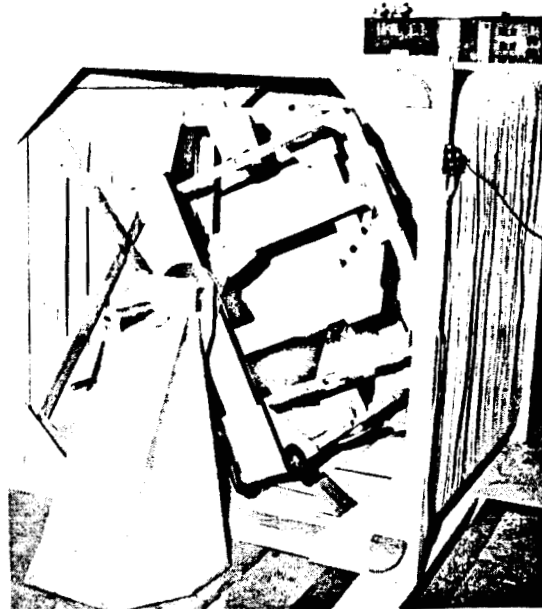


Figure C-3—Tumbler inside coil.

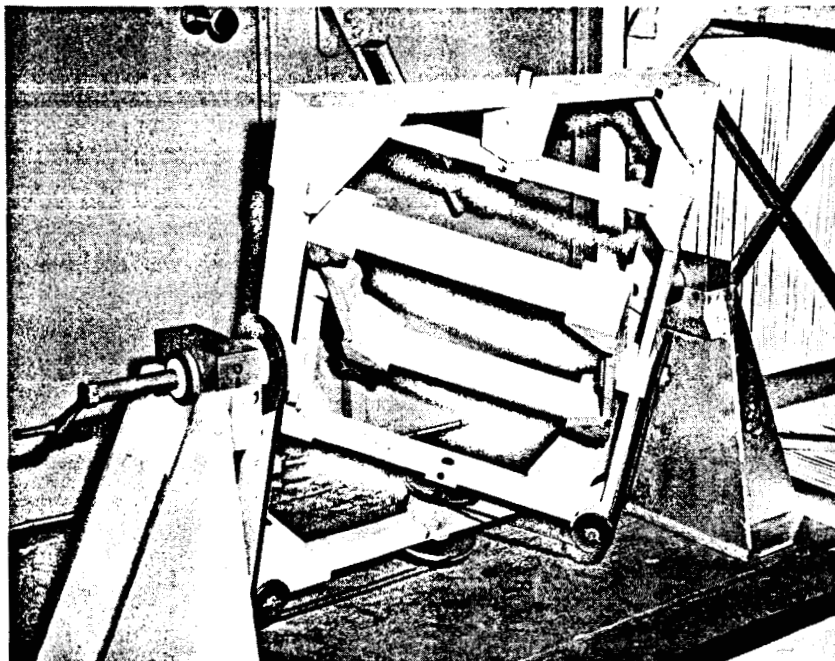


Figure C-4—Tumbler removed from coil.

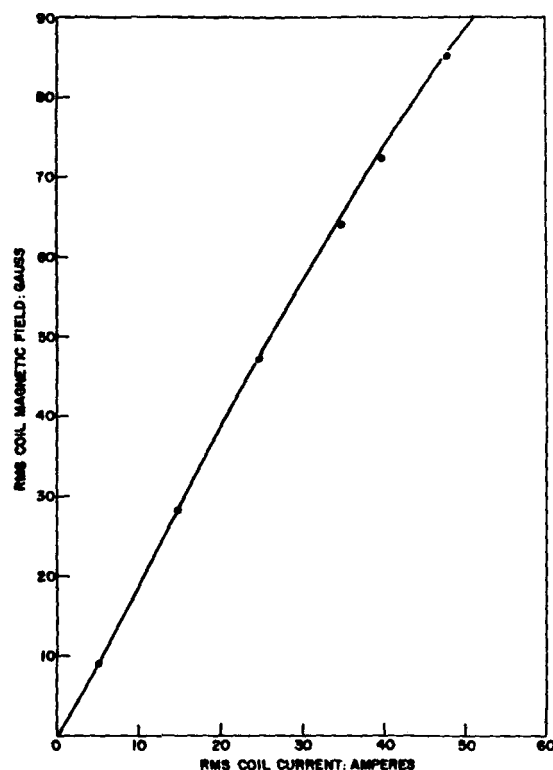


Figure C-5—Coil calibration curve.

The coil has a dc resistance of 2.14 ohms (measured hot, i. e. after reaching an operating temperature of 50°C) and an inductance of 62 millihenries. At 60 cps, the inductive reactance ($2\pi fL$) of the coil is 23 ohms. A supply voltage of 120 volts was sufficient to produce 50 amperes coil current when the coil was resonated with a series capacitor bank of 106 microfarads. The exact capacitance was determined by trial and error during tests; the coil was calibrated (Figure C-5) with an RFL Model 1890 gaussmeter and was found to produce 120 gauss (peak value) for an rms current of 50 amperes.

Figure C-6 is a schematic diagram of the ac demagnetization apparatus. The General Radio variac, source of the variable voltage, is driven by a variable speed dc motor through an 800:1 reduction gear.

THE AC DEMAGNETIZATION PROCEDURE

The desired maximum field is established in the coil. The component to be demagnetized is placed within the inmost rectangular frame of the tumbler apparatus (the frame being removable for convenient placement of the package). The variac wiper is set to the desired speed and the tumbling action begins. The component is tumbled until the variac wiper has completed its traverse from maximum voltage to zero.

In the Workshop operation, the outer frame of the tumbler was rotated at a speed of about 40 rpm for initial evaluation of the apparatus; the variac completed its traverse within a 10-minute period.

DESCRIPTION OF SAMPLES

Samples used in the tests were furnished by the Magnetic Test Section at Goddard, and consisted of:

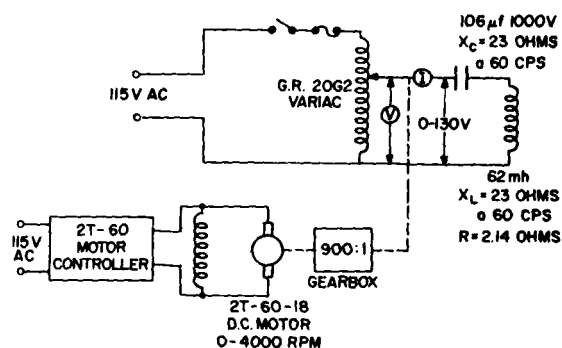


Figure C-6—AC demagnetization apparatus, schematic diagram.

- A cylindrical steel rod 3.5 inches long, 1 inch in diameter
- A cylindrical steel rod 12.5 inches long, 0.25 inch in diameter
- An amplifier chassis box containing transistors, transformers, potentiometers, capacitors, etc.

The samples were magnetized in a dc field of 25 gauss, and the axial component of the resulting remanent magnetization was measured at a distance of 24 inches from the center of the sample. Measured values are listed in Table C-1a.

DISCUSSION OF RESULTS

A comparison of the field intensity remaining in the samples after ac deperming and after dc deperming is shown in Tables C-1b and C-1c. For the steel rods, the ac deperming is more effective than the dc deperming by a factor of 6.

Table C-1—Comparison of AC and DC Deperming

Sample	12.5" rod	3.5" rod	Component Box
(a) All magnetic fields measured at 24" from center of sample.			
Original field (gammas) after 25-gauss exposure	1900	15	150
(b) After dc deperming			
Magnetic field remaining (gammas) after treatment at dc field strength of 50 gauss	5.6	3.0	7.3
Percentage field remaining (original field as base)	0.29	20	4.8
Percentage demagnetization (original field as base)	99.68	80	95.8
(c) After ac deperming			
Magnetic field remaining (gammas) after treatment at peak ac field strength of 120 gauss	1.0	0.5	1.4
Percentage field remaining (original field as base)	0.053	3.3	0.93
Percentage demagnetization (original field as base)	(approx.) 100	96.6	99

This comparison, however, is not strictly fair to either the dc or the ac technique, as it does not allow for the fact that the samples were depermed in an ac field strength of 120 gauss, whereas the maximum field available for dc deperming is 50 gauss. Likewise, in the dc process, the samples were demagnetized along a premeasured axis of maximum permanent field intensity; in the ac process, the rods were tumbled and all directions were subjected to the ac field. It is possible that an even larger percentage of the permanent field could have been removed if, in the ac process, the rods were also fixed with their axis of maximum field intensity aligned with the axis of the coil. The advantage of the tumbling action is not as great in demagnetizing rods as it would be in demagnetizing a component with a multipole field.

The third sample, the amplifier, is more representative of a satellite component with a highly irregular field. Deperming by the ac process decreased the residual field to 0.93 percent of its initial value, while dc deperming decreased the field to 4.8 percent of its initial value.

The graph shown in Figure C-7 is a fairer comparison of the two methods of deperming. A previous study of initial dc demagnetization field strength versus remanent field strength after dc deperming has been made by the Magnetic Test Section for the 3.5-inch rod; similar data were obtained by using ac deperming.

The rod was depermed in peak alternating fields of 120, 75, and 50 gauss (the 50-gauss points on the curves provide a comparison of the two methods). The field after dc deperming was 3.0 gamma; after ac deperming, 0.8 gamma. These data indicate that tumbling in an ac field is the more effective procedure.

Figure C-7 also shows data obtained by ac deperming at peak field strengths of 75 and 120 gauss. There is little decrease in the residual magnetism of the rod after the 50-gauss exposure.

No attempt was made to null the background field of the earth for these ac deperming experiments; a field-free facility was available for dc deperming.

CONCLUSIONS

1. Initial tests indicate ac tumbling is more effective than dc deperming.

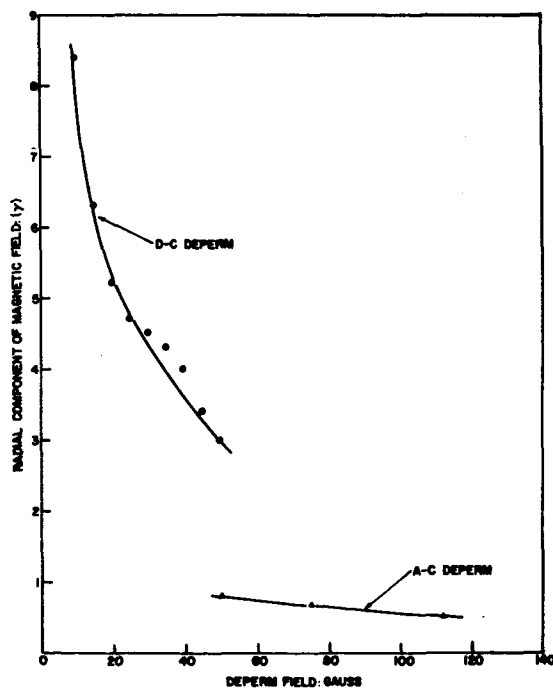


Figure C-7—Demagnetization of 3.5-inch steel rod as a function of initial field strength.

2. Tumbling of the component is an important factor in the demagnetization process.
3. A field-free space, though certainly helpful, is not a major requirement for demagnetization by ac tumbling.

SUGGESTIONS FOR FURTHER STUDY

Additional tests should be made using magnetic materials with larger coercive forces to determine the upper limit of effectiveness of this apparatus.

Effectiveness of the ac demagnetization should be analyzed as a function of

- speed of rotation of sample
- maximum initial demagnetization field
- rate of decrease of field

to determine optimum conditions for reduction of remanent magnetism to a minimum intensity.

All measurements in this report were made through the courtesy of C. Leland Parsons and the men of the Magnetic Test Section. Their cooperation, consultation, and encouragement are greatly appreciated by the author.

REFERENCES

1. Creer, K. M., "AC Demagnetization of Unstable Triassic Keuper Marls," *Geophys. Jour.* 2, 261-275 (1959)
2. Irving, E., Scott, P., and Ward, M., "Demagnetization of Igneous Rocks by Alternating Magnetic Fields," *The Phil. Mag.* 6, 225-241 (1961)